Chapter 5
Projected Greenhouse Gas Emissions

This chapter provides estimates for national emissions under many of the implemented policies and measures for reducing emissions through technology improvements and dissemination, demand-side efficiency gains of many specific types, more efficient regulatory procedures, and shifts to cleaner fuels. The anticipated expansion of the U.S. economy under the impetus of population and output growth at projected rates contributes to rising greenhouse gas emissions. These emissions are partly offset by reductions from ongoing efforts to decrease energy use and from implemented policies and measures. Even with projected growth in absolute emissions, there are near-term and continuing reductions in emissions per unit of gross domestic product (GDP). These projections do not include the impact of the President's climate change initiative announced in February 2002, nor do they include the effects of policies in the *National Energy*

Policy that have not yet been implemented (NEPD Group 2001).

THE NEMS MODEL AND POLICIES COVERAGE

The U.S. Department of Energy's (DOE's) *Annual Energy Outlook 2002* (AEO 2002) presents mid-term forecasts of energy supply, demand, and prices through 2020 based on results from the Energy Information Administration's National Energy Modeling System (NEMS) (U.S. DOE/EIA 2001a). This integrated model looks at all determinants of carbon emissions simultaneously, accounting for interaction and feedback effects. But in some cases, it uses assumptions about diffusion and adoption rates that are different from the assumptions used for the independent policies and measures estimates in Chapter 4 of this report.

The NEMS uses a market-based approach that balances supply and demand with price competition between fuels and sectors. It is a comprehensive, but simplified, representation of the energy economy. Rather than explicitly including and replicating every transaction, the NEMS measures aggregate impacts using empirically developed statistical proxies. Its strength lies in the consistency it brings in representing and accounting for the large number of concurrent, interrelated, and competing energy transactions, investment transactions, and production and consumption decisions that occur in the national energy sector.

The AEO 2002 projections are based on the assumption that the trend in funding levels for policies continues to follow historical patterns. Policies or programs adopted since July 2001—such as the Green Power Partnership, the Combined Heat and Power Partnership, and the Ground Freight Transportation Initiative—are not included in these emission estimates. The methods used to create the projections are regularly updated as new information and methods emerge. However, there is a time lag in the representation of the future effects of some of the adopted measures when using an economic model based on history, such as the NEMS. Consequently, actual growth in energy use and emissions may be different from the projected levels, and the AEO 2002 projections should not be interpreted as reflecting the ultimate impact of policies and measures over the 20-year horizon.

The reported impacts of the individual policies and measures in Chapter 4 of this report are based on specific assumptions for the impacts and adoption of each measure. However, those impacts recognize fewer interaction and competitive effects within and among the economic sectors in which the individual measures are applied. A precise mapping of the emission reductions from individual policies and measures against the aggregate estimates of the NEMS used in the AEO modeling exercise is not possible. Readers are cautioned not to interpret the difference between the estimates in Chapter 4 and this chapter as the numeric difference between the "with measures" and "without measures" cases. The direct impact measures of Chapter 4 compare the effects of provisions that avoid large interaction effects between each other or broadly competitive alternatives. The NEMS results, which address interaction effects and potentially nonmarginal changes, reflect integrated responses to a comprehensive set of economic variables.

Assumptions Used to Estimate Future CO_2 Emissions

This projection of emissions for distant future years is always subject to certain assumptions and uncertainties. These assumptions relate to the prospective implementation and funding of policies and measures adopted but not yet funded; to the actual discovery, adoption, and efficacy of technologies not yet tested in the marketplace; and to the pace of future economic growth.

The AEO 2002 projects a declining ratio of emissions to GDP by incorporating the impacts—including costs—of legislation and regulations adopted as of July 1, 2001. These provisions include, for example, rising appliance efficiencies driven by upgraded ENERGY STAR® specifications for products and homes, progressive upgrades to commercial lighting, and adoption of electric and alternative-fuel vehicles in accord with federal and state requirements. Utility Climate Challenge plans are represented in large measure, with the exception of tree-planting programs and purchases of emission offsets. Renewable-fuels power generation is included, consistent with announced utility building plans through 2020. A description of the policies and measures and technology assumptions embodied in the AEO projections is provided in Appendix G of the AEO 2002.

The assumptions under which the AEO 2002 estimates were prepared include real GDP growth of 3 percent annually over the 20-year period, without specific regard to interim business cycles. The degree of technology improvement reflected in the projections is internally generated in the modeling process based on the Energy Information Administration's judgment about the market readiness, cost, and performance of available technologies, their rates of adoption, and their potential for efficiency improvement. Based on the AEO 2002 estimates, real oil prices are expected to average just over $21 a barrel in 2002, and then rise gradually to $24–$25 a barrel by 2020. Natural gas supplies are assumed to be adequate to support the projected growth in demand. Natural gas prices are projected to rise from just over $2 per thousand cubic feet in 2002, to $3.26 in real terms per thousand cubic feet in 2020. The projection exercise assumes that current laws and regulations will continue in force, but does not anticipate measures not yet enacted or implemented.

Table 5-1 presents several measures of the U.S. economy that generate energy consumption and related carbon emissions, and compares the values used in the 1997 *U.S. Climate Action Report* (CAR) to those relied upon for this report. In this 2001 CAR, 2020 real GDP is notably higher, energy intensity per dollar of GDP is notably lower, natural gas prices are higher, and gasoline prices are lower compared to the levels assumed in the 1997 CAR.

U.S. GREENHOUSE GAS EMISSIONS: 2000–2020

This report contains reported levels of greenhouse gas emissions for the year 2000 and estimates to 2020. The projections of U.S. greenhouse gas emissions described here reflect national estimates of net greenhouse gas emissions considering population growth, long-term economic growth potential, historical rates of technology improvement, normal weather patterns, and many of the implemented policies and measures. The covered gases include carbon dioxide (CO_2), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

DOE's Energy Information Administration computed the energy-related CO_2 projections and the estimated adjustments for bunker fuel use (U.S. DOE/EIA 2001a). The U.S. Environmental Protection Agency (EPA) prepared the emission projections for source categories other than CO_2 emissions resulting from fossil fuel consumption (U.S. EPA 1999; 2001a, b, d). And the U.S. Department of Agriculture (USDA) prepared the estimates of carbon sequestration rates (USDA 2000). The projections reflect long-run trends and do not attempt to mirror short-run departures from those trends.

Rather than the carbon tonnages often used in the United States, emission projections in this report are converted to metric tons of carbon dioxide equivalents, in keeping with the reporting guidelines of the United Nations Framework Convention on Climate Change (UNFCCC). The conversions of non-CO_2 gases to CO_2 equivalents are based on the 100-year global warming potentials (GWPs) listed in the Intergovernmental Panel on Climate Change's (IPCC's) second assessment report (IPCC 1996b).

U.S. greenhouse gas emissions from energy consumption, industrial and agricultural activities, and other anthropogenic sources continued to grow from levels reported in the 1997 *U.S. Climate Action Report* (Figure 5-1). However, emissions of a few of the non-CO_2 gases—e.g., methane and industrial gases associated with the production of aluminum and HCFC-22—have declined from 1990 levels and are projected to remain below 1990 levels out to 2020 (Figure 5-2).

As shown in Figure 5-1, while carbon sequestration partly offsets gross emissions of greenhouse gases, net emissions are projected to rise nonetheless under the impetus of population and economic growth. Increased efforts to use cleaner fuels, improved technologies, and better management methods for agriculture, forestry, mines, and landfills have kept the growth of greenhouse gas emissions below the concurrent growth of the U.S. economy. The policies and measures described in Chapter 4 of this report are expected to further decouple economic growth and greenhouse gas emissions.

The most recent historical measures of greenhouse gas emissions are for 2000, but these measures are still preliminary and are thus subject to possible revision after this report's publication. Nevertheless, the projections use the report's preliminary 2000 data as a point of departure for estimating greenhouse

TABLE 5-1 Comparison of 1997 and 2001 CAR Assumptions and Model Results

Several sectors of the U.S. economy involve energy consumption and related carbon emissions. This table compares the values used in the 1997 *U.S. Climate Action Report* (CAR) to those relied upon for this report. In this 2001 CAR, 2020 real GDP is notably higher, energy intensity per dollar of GDP is notably lower, natural gas prices are higher, and gasoline prices are lower compared to the levels assumed in the 1997 CAR.

Factors	2000		2010		2020	
	1997 CAR	*2001 CAR*	*1997 CAR*	*2001 CAR*	*1997 CAR*	*2001 CAR*
Real GDP *(billions of 1996 dollars)*	8,152	9,224	9,925	12,312	11,467	16,525
Population *(millions)*	276	276	299	300	324	325
Residential Housing Stock *(millions)*	103.0	105.2	114.7	116.0	125.4	127.1
Commercial Floor Space *(billion sq. ft.)*	72.3	64.5	78.5	77.5	85.3	89.6
Energy Intensity *(Btus per 1996 dollar GDP)*	11,903	10,770	10,572	9,400	9,631	7,920
Light-Duty Vehicle Miles Traveled *(billions)*	2,373	2,340	2,885	2,981	3,368	3,631
Energy Commodity Prices						
World Oil Price *(2000 dollars/barrel)*	19.86	27.72	22.16	23.36	24.18	24.68
Wellhead Natural Gas *(2000 dollars/1,000 cu. ft.)*	2.02	3.60	2.16	2.85	2.61	3.26
Minemouth Coal *(2000 dollars/ton)*	19.60	16.45	18.00	14.11	16.70	12.79
Average Price Electricity *(2000 cents/kWh)*	7.31	6.90	6.98	6.30	6.66	6.50
Average Price Gasoline *(2000 dollars/gallon)*	1.49	1.53	1.52	1.40	1.56	1.40

FIGURE 5-1 Gross and Net U.S. Greenhouse Gas Emissions: 2000–2020

Although carbon sequestration partly offsets gross greenhouse gas emissions, net emissions are projected to increase nonetheless under the impetus of population and economic growth.

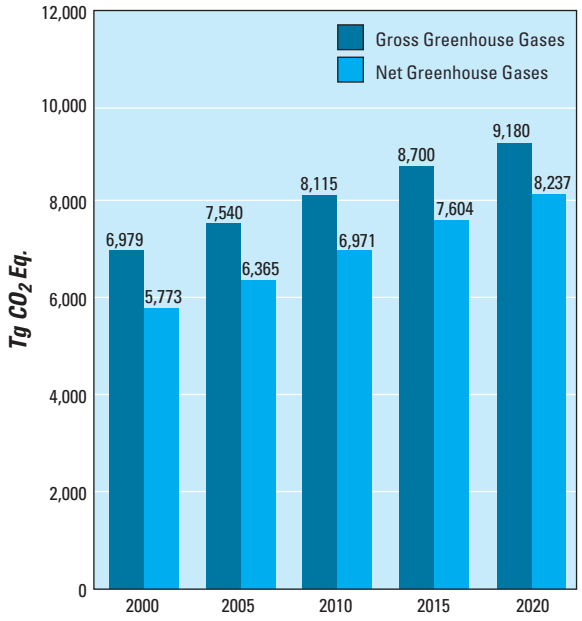
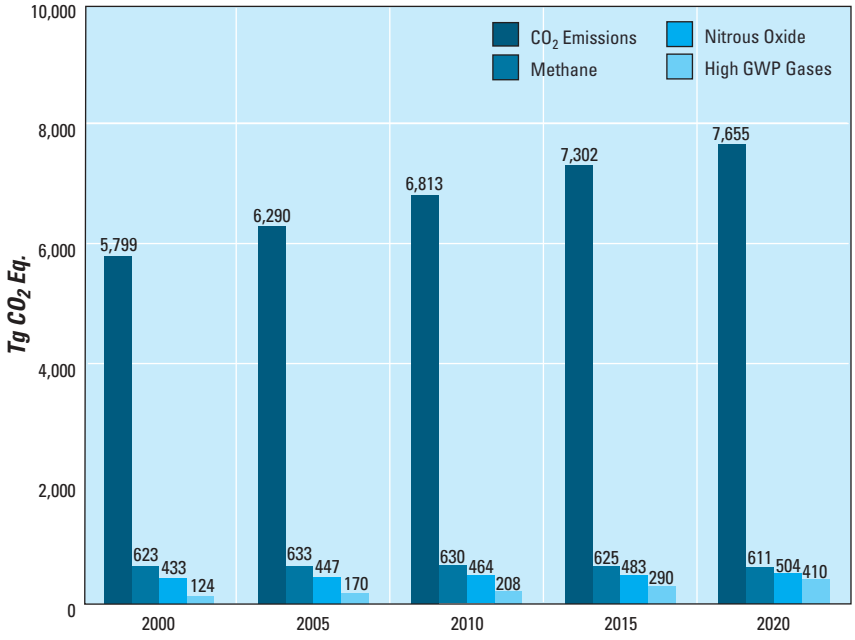


FIGURE 5-2 U.S. Greenhouse Gas Emissions by Gas: 2000–2020

A few of the non-CO_2 gases—e.g., methane and industrial gases associated with the production of aluminum and HFC-22—have declined from 1990 levels and are projected to remain below 1990 levels out to 2020.



Note: CO_2 emissions reported are net of adjustments.

gas emissions at the 5-year interval benchmarks of 2005, 2010, 2015, and 2020. The text that follows describes changes in emission levels and intensities to the end-point year 2020.

Net U.S. Greenhouse Gas Emissions: 2000–2020

The total projected levels of U.S. greenhouse gas emissions are tallied by (1) combining the CO_2 contributions of energy and nonenergy activities and the non-CO_2 greenhouse gas emissions of methane, nitrous oxide (including forestry and agriculture), and the high GWP gases; (2) subtracting for projected levels of carbon sequestration; and (3) making noted adjustments. Because some of the individual greenhouse gas emissions apart from energy-related portions are not attributed to particular economic sectors, the totals are reported in aggregate.

Total net U.S. greenhouse gas emissions are projected to rise by 42.7 percent, from 5,773 teragrams of CO_2 equivalent (Tg CO_2 Eq.)[1] as the (preliminary) actual level for 2000, to 8,237 Tg CO_2 Eq. projected for 2020 (Table 5-2). However, when examined by 5-year intervals, the rate of increase in U.S. greenhouse gas emissions is expected to diminish over the 20-year projection period. The declining 5-year growth rates reflect the influence of development and implementation of cleaner, more efficient technologies that reduce the ratio of greenhouse gas emissions to GDP over the period; the substitution of fuels that emit lower volumes of greenhouse gases; and changes in the composition of GDP to goods and services with fewer fuel inputs. Some of the mitigating factors are also the subject of implemented policies and measures that reduce emissions relative to a hypothetical "business as usual" path. In addition, there are adopted policies and measures, not yet fully implemented, and the possibility of additional policies and measures prior to 2020 that are not yet defined, which together may further reduce the

[1] One teragram equals one million metric tons.

TABLE 5-2 Projected U.S. Greenhouse Gas Emissions from All Sources: 2000–2020 (Tg CO_2 Eq.)

Between 2000 and 2020, total net U.S. greenhouse gas emissions are projected to rise by 42.7 percent. However, the rate of increase in emissions is projected to diminish over the same period, reflecting the development and implementation of cleaner, more efficient technologies; the substitution of fuels that emit lower volumes of greenhouse gases; and changes in the composition of GDP to goods and services with fewer fuel inputs.

All Covered Sources	2000	2005	2010	2015	2020
Energy-Related CO_2	5,726	6,210	6,727	7,206	7,655
Non-energy CO_2	132	138	145	153	161
Methane	623	633	630	625	611
Nitrous Oxide	433	447	464	483	504
High GWP Gases	124	170	208	290	410
Sequestration Removals	-1,205	-1,175	-1,144	-1,096	-1,053
Adjustments	- 59	- 58	- 59	- 57	- 51
Total	**5,773**	**6,366**	**6,972**	**7,604**	**8,237**

GWP = global warming potential.

Notes: These total U.S. CO_2 equivalent emissions correspond to carbon weights of 1,574 teragrams (Tg) for year 2000; 1,901 Tg for 2010; and 2,246 Tg for 2020. Totals may not sum due to independent rounding.

20-year greenhouse gas path below the aggregate and sectoral levels projected in this report.

The projected emission levels of this report for the years 2010 and 2020 are higher than the levels projected for those same years in the 1997 *U.S. Climate Action Report*, and the preliminary actual level of emissions reported for 2000 is lower than the 1997 projected value. The sections that follow present more detailed projections of specific categories of total U.S. greenhouse gas emissions.

CO_2 Emissions

From 2000 to 2020, energy-related CO_2 emissions are projected to increase by 33.6 percent, compared to cumulative projected economic growth of 80 percent (Table 5-3). The nation's carbon intensity has declined from 721 grams of CO_2 per dollar of GDP in 1990 to 621 grams per dollar in 2000, and is projected to decline further to 463 grams per dollar of GDP by 2020.

In the first 5-year interval, CO_2 emissions are projected to grow by 1.6 percent annually, but by the final 5-year period growth in emissions will have diminished to 1.2 percent annually. The estimated level of U.S. CO_2 emissions from energy-related activities for the year 2020 is 7,655 Tg CO_2. This level of emissions results from the projected long-term economic, technological, and demographic path, and from the impacts of implemented policies and measures. Additional policies and measures, adopted but not yet implemented—including both new recommendations of the *National Energy Policy* and expanded emphasis on some measures already implemented—could further reduce U.S. CO_2 emissions for 2020 and interim years.

The rising absolute levels of greenhouse gas emissions for the entire U.S. economy occur against a background of growth assumptions for population and GDP. Over the 20-year period, population and personal income are projected to rise respectively by 18 and 79 percent.

- The CO_2 emission intensity of the *residential sector* is expected to decline by 30 percent, while the sector's contributions of CO_2 are estimated to rise by 25 percent, to a total of 1,397 Tg CO_2 annually by 2020. Over the same period, the sector is expected to contribute a diminishing share of total U.S. CO_2 emissions.
- The projected CO_2 emission intensity of the *commercial sector* is expected to decline by 16 percent over the 20-year interval, as measured against the projected 79 percent increase in GDP. The sector's absolute emission contributions are estimated to rise by 42.5 percent to a total of 1,363 Tg CO_2 annually by 2020. Over the 20-year projection period, the commercial sector is expected to contribute a rising share of total U.S. CO_2 emissions.
- The projected CO_2 emission intensity of the *industrial sector* is expected to decline by 27 percent over the 20-year interval, as measured against the projected 79 percent increase in GDP. The sector's absolute emission contributions are estimated to rise by 22 percent to a total of 2,135 Tg CO_2 annually by 2020. Over the 20-year projection period, the industrial sector is expected to contribute a diminishing share of total U.S. CO_2 emissions.
- The projected CO_2 emission intensity of the *transportation sector* is expected to decline by 19 percent over the 20-year interval, as measured against the projected 79 percent increase in GDP. The sector's absolute emission contributions are estimated to rise by 46 percent to a total of 2,760 Tg CO_2 annually by 2020. Over the 20-year projection period, the transportation sector is expected to contribute a rising share of estimated total U.S. CO_2 emissions, reflecting the growth of travel demand and the relatively limited projected use of low-emission fuels even by 2020.

Nonenergy CO_2 Emissions

Other, nonfuel, sources that emit CO_2 include natural gas production and processing, the cement industry, and waste handling and combustion. These CO_2 emissions are subject to increasing voluntary control and are using recapture technologies to reduce their emission levels. Because the underlying sources are so varied, no clear projection method, other than

historical extrapolation, is available. These sources are projected to grow by 1 percent annually, well below the 79 percent GDP growth rate assumed in the fuel emission projections. These nonfuel emissions are projected to grow from 132 Tg CO_2 in 2000 to 161 Tg CO_2 in 2020.

CO_2 Emissions from the Electricity Sector

Electricity generation typically produces significant CO_2 emissions, with the important exceptions of electricity generated from nuclear power and from renewable sources, such as hydropower, geothermal, wind, biomass and biomass conversion, and solar power applications. While electricity producers differ greatly in their reliance on various primary fuel inputs, their overall CO_2 contributions are attributable to the nationwide electricity purchases of customers in all economic sectors.

The electricity sector's CO_2 emission intensity is projected to decline by 6 percent over the 20-year interval, as measured against a 43 percent projected increase in total sales of electric energy. Absolute emissions contributions from the electricity sector are estimated to rise by 35 percent during the same period to a total of 2,897 Tg CO_2, reflecting rising electric power sales from 2000 to 2020. The sector's share of total U.S. CO_2 emissions is expected to rise as well, due to the growing role of electricity in powering activities in all economic sectors.

By 2020, the mix of primary fuels in electricity production is expected to be significantly different from the mix during 2000. The expanding role of natural gas, with its relatively low greenhouse gas impact, and the growing dominance of highly efficient generation technologies are projected to reduce the sector's greenhouse gas emissions to a level far below what they would have been without these changes. As noted above, the emission intensity of electricity production is estimated to decline significantly over the projection period. By fuel type, the 2020 CO_2 emissions from electricity generation are 22 Tg CO_2 for energy generated from petroleum, 554 Tg CO_2 for energy generated from natural gas, and 2,322 Tg CO_2 for generation from coal (Table 5-4). Greenhouse gas emissions from nuclear and renewable sources are essentially zero.

TABLE 5-3 U.S. CO_2 Emissions by Sector and Source: 2000–2020 (Tg CO_2)

Improvements in CO_2 emission intensity and the absolute levels of future CO_2 emissions vary among economic sectors. The projected 1 percent annual growth in CO_2 emissions from nonenergy sources is well below the 79 percent GDP growth rate assumed in the fuel emission projections.

Sector/Source	2000	2005	2010	2015	2020
Residential	**1,122**	**1,223**	**1,269**	**1,325**	**1,397**
Petroleum	101	95	90	86	83
Natural Gas	268	292	300	311	325
Coal	4	4	5	5	5
Electricity	748	832	874	924	985
Commercial	**957**	**1,057**	**1,163**	**1,264**	**1,363**
Petroleum	52	48	50	51	51
Natural Gas	181	199	213	228	245
Coal	7	6	7	7	7
Electricity	717	803	893	979	1,059
Industrial	**1,753**	**1,818**	**1,951**	**2,049**	**2,135**
Petroleum	344	362	393	414	432
Natural Gas	499	541	581	612	632
Coal	239	231	232	234	237
Electricity	671	684	745	790	834
Transportation	**1,895**	**2,112**	**2,345**	**2,568**	**2,760**
Petroleum	1,843	2,055	2,280	2,495	2,679
Natural Gas	42	45	50	57	61
Other	0	*	*	*	*
Electricity	11	13	14	16	19
Total Energy Uses	**5,726**	**6,210**	**6,727**	**7,206**	**7,655**
Petroleum	2,339	2,560	2,813	3,045	3,245
Natural Gas	990	1,077	1,145	1,208	1,263
Coal	250	242	244	245	249
Other	0	*	*	*	*
Electricity	2,147	2,331	2,526	2,709	2,897
Nonenergy CO_2 Emissions	**132**	**138**	**145**	**153**	**161**
Natural Gas Production	39	40	41	43	44
Industrial Processes	92	98	104	110	117
Total CO_2 Emissions	**5,858**	**6,348**	**6,872**	**7,359**	**7,816**

Note: Totals may not sum due to independent rounding.

** = less than 0.5 Tg.*

Sectoral CO_2 Emissions from Electricity Use

Customers in all sectors use electricity. In that sense, the greenhouse gas emissions that result from electricity production and distribution can be attributed to the end-use sectors (Table 5-5).

- Electricity demand by the **residential sector** is projected to rise by 40 percent from 2000 to 2020, while the CO_2 emissions from the sector's electricity consumption are projected to rise by 31.7 percent. The absolute level of projected CO_2 emissions attributable to the residential sector from electricity use in 2020 is 985 Tg CO_2.
- Electricity demand by the **commercial sector** is projected to rise by 49 percent from 2000 to 2020, while the CO_2 emissions from the sector's electricity consumption are

projected to rise by 47.7 percent. The absolute level of projected CO_2 emissions attributable to the commercial sector from electricity use in 2020 is 1,059 Tg CO_2.

- Electricity demand by the **industrial sector** is projected to rise by 32 percent from 2000 to 2020, while the CO_2 emissions from the sector's electricity consumption are projected to rise by 24.2 percent. The absolute level of projected CO_2 emissions attributable to the industrial sector from electricity use in 2020 is 834 Tg CO_2.
- Emissions of CO_2 from the **transportation sector's** electricity use are projected to rise by 71 percent from 2000 to 2020. However, this sector's overall electricity use is expected to remain small, constituting less than 1 percent of total U.S. electricity demand in 2020.
- For all sectors, demand for **electricity** is projected to grow more rapidly than direct fuel use in other sectors, as electricity assumes an expanding role in meeting the energy demands of the U.S. economy. Emissions of CO_2 from the electricity sector are projected to rise by 34.9 percent over the 20-year projection period. Efficient production and use of electricity, as well as development of clean fuels, will be a continuing policy focus for the United States.

U.S. CO_2 Emissions from Energy Activities

Total CO_2 emissions are projected to increase by 33.4 percent from 2000 to 2020, to an absolute level of 7,816 Tg CO_2 (Table 5-6). By contrast, cumulative GDP growth over the same period is projected at 79 percent. Consolidating end-use sectors and the electricity industry to examine the projected levels of CO_2 emissions by principal primary fuels shows a growing relative share for natural gas emissions, reflecting rising natural gas use. This share growth for natural gas is an important cause of the declining ratio of greenhouse gas—particularly CO_2—emissions to U.S. economic output.

Emissions of CO_2 from primary fuels are projected to rise as follows: petroleum, 35.4 percent; natural gas, 49.7 percent; and coal, 22.4 percent. Emissions of CO_2 from the ancillary power needs for electricity generation from non-fossil fuels—primarily nuclear and hydro-power, but also including other renewable sources—remain at negligible levels (less than 0.4 Tg CO_2), even though the utilization of low-emission energy sources is expected to double by 2020. Natural gas is projected to meet a growing share of U.S. energy demand; coal, a reduced share; and petroleum fuels, approximately the same share. The impact of the changing shares of primary fuels is to reduce the intensity of the GDP's greenhouse gas emissions. Nonenergy CO_2 emissions are expected to grow by 22 percent over the projection period.

TABLE 5-4 U.S. CO_2 Emissions from Electricity Generators: 2000–2020 (Tg CO_2)

By 2020, the mix of primary fuels in electricity production is expected to be significantly different from the mix during 2000.

Primary Fuel	2000	2005	2010	2015	2020
Petroleum	73	25	116	19	22
Natural Gas	224	295	369	479	554
Coal	1,850	2,011	2,141	2,211	2,322
Total	**2,147**	**2,331**	**2,526**	**2,709**	**2,898**

Note: Totals may not sum due to independent rounding.

TABLE 5-5 Sectoral U.S. CO_2 Emissions from Electricity Use: 2000–2020 (Tg CO_2)

For all sectors, demand for electricity is projected to grow more rapidly than direct fuel use in other sectors, as electricity assumes an expanding role in meeting the energy demands of the U.S. economy. Emissions of greenhouse gases from the electricity sector are projected to rise by 34.9 percent over the 20-year projection period.

Sector	2000	2005	2010	2015	2020
Residential	748	832	874	924	985
Commercial	717	803	893	979	1,059
Industrial	671	684	745	790	834
Transportation	11	13	14	16	19
Total	**2,147**	**2,331**	**2,526**	**2,709**	**2,898**

Note: Totals may not sum due to independent rounding.

Non-CO_2 Greenhouse Gas Emissions

Emissions other than CO_2 include methane emissions from natural gas production and transmission, coal mine operation, landfills, and livestock operations; nitrous oxide emissions from agriculture and, to a lesser degree, transportation; and hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6) gases from industrial activities and, in some cases, the life cycles of the resulting products (Table 5-7).

Methane

Methane emissions are estimated for 1990 and 2000, and over the 5-year benchmarks of 2005, 2010, 2015, and 2020 (U.S. EPA 1999, 2001a). Over this period, total methane emissions are estimated to decline by 5.2 percent, primarily due to reductions in methane emissions from coal mines and landfills. However, this decline is expected to be offset in part by rising methane emissions from livestock operations. Projected methane emissions from natural gas production, transportation, and use remain nearly unchanged, as the rising natural gas volumes produced and transported are governed by policies and practices that

will curtail methane releases with increasing effectiveness over the projection period.

Natural Gas Operations. Methane emissions from natural gas operations are projected to increase from 116 Tg CO_2 Eq. in 2000 to 119 Tg CO_2 Eq. in 2020—an increase of only 2.5 percent, despite the more than 60 percent projected increase in natural gas use over the 20-year period.

Coal Mine Operations. Methane emissions from coal mine operations are projected to decline from 70 Tg CO_2 Eq. in 2000 to 66 Tg CO_2 Eq. in 2020—a decrease of 6 percent, primarily due to the closure of very gassy mines and to a projected shift in coal production from underground to surface mines. Coal mine methane is subject to continually improving management practices. This decline in coal-related methane emissions is expected, despite the more than 20 percent increase in coal production projected over the 20-year period.

Landfills. Landfill methane emissions are projected to decrease from 214 Tg CO_2 Eq. in 2000 to 186 Tg CO_2 Eq. in 2020—a decrease of 13 percent, despite growing volumes of municipal waste in place over the period. Landfill sites are assumed to be subject to continually improving methane recovery practices over the 20-year period.

Livestock Operations and Other Activities. Methane emissions from livestock operations, manure management, and other activities not separately listed are expected to rise from 224 Tg CO_2 Eq. in 2000 to 240 Tg CO_2 Eq. in 2020—an increase of 10.3 percent. Anticipated emission management practices for the agricultural and other categories do not fully offset projected agricultural growth over the 20-year period.

Total Methane Emissions. Total U.S. methane emissions from all sources are projected to decline from 623 Tg CO_2 Eq. in 2000 to 611 Tg CO_2 Eq. in 2020—a decrease of 2.1 percent.

HFCs, PFCs, and SF_6

Emissions of HFCs, PFCs, and SF_6 are estimated by EPA for 1990, 2000, and over the 5-year interval benchmarks of 2005, 2010, 2015, and 2020 (U.S. EPA 2001e). While total emissions are projected to rise from 124 Tg CO_2 Eq. in 2000 to 410 Tg CO_2 Eq. in 2020, this increase is expected to be predominantly from the use of HFCs as replacements for ozone-depleting substances (ODS). Growth in the use of HFCs will allow rapid phase-out of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and halons in a number of important applications where other alternatives are not available.

HFCs are expected to be selected for applications where they provide superior technical (reliability) or safety

TABLE 5-6 U.S. CO_2 Emissions from All Sectors: 2000–2020 (Tg CO_2)

The growing relative share of natural gas emissions resulting from the increased use of natural gas is an important cause of the declining ratio of greenhouse gas—particularly CO_2—emissions to U.S. economic output.

Primary Fuel /Source	2000	2005	2010	2015	2020
Primary Fuel CO_2	**5,725**	**6,210**	**6,728**	**7,206**	**7,655**
Petroleum	2,411	2,584	2,829	3,063	3,266
Natural Gas	1,214	1,372	1,513	1,687	1,817
Coal	2,100	2,253	2,385	2,456	2,571
Non-energy CO_2	**132**	**138**	**145**	**153**	**161**
Total CO_2	**5,857**	**6,348**	**6,873**	**7,359**	**7,816**

Note: Totals may not sum due to independent rounding.

TABLE 5-7 Non-CO_2 Emissions: 2000-2020 (Tg CO_2 Eq.)

Emissions other than CO_2 include methane emissions from natural gas production and transmission, coal mine operation, landfills, and livestock operations; nitrous oxide emissions from agriculture and, to a lesser degree, transportation; and HFC, PFC, and SF_6 gases from industrial activities.

Non-CO_2 GHG/Source	2000	2005	2010	2015	2020
Methane Emissions	**623**	**634**	**630**	**625**	**611**
Natural Gas	116	115	115	117	119
Coal Mines	70	73	72	71	66
Landfills	214	219	213	202	186
Livestock Operations	163	167	171	175	178
Other	61	60	59	61	62
High GWP Substances	**124**	**170**	**208**	**290**	**410**
ODS Substitutes (HFCs)	58	119	171	266	392
Aluminum (PFCs)	8	7	6	6	5
HCFC-22 (HFC-23)	30	11	6	3	0
Stewardship Programs (Semiconductors, Magnesium, Electric Power Systems, New Programs; HFCs, PFCs, SF_6)	28	33	24	15	13
Nitrous Oxide	**433**	**447**	**464**	**483**	**504**
Agriculture	317	326	336	343	350
Mobile Combustion	62	62	66	74	83
Other	54	59	62	66	71
Total	**1,180**	**1,250**	**1,302**	**1,398**	**1,686**

Note: Totals may not sum due to independent rounding.

(low toxicity and flammability) performance. In many cases, HFCs provide equal or better energy efficiency compared to other available alternatives, and their acceptance in the market will reduce long-term environmental impacts. HFCs are expected to replace a significant portion of past and current demand for CFCs and HCFCs in insulating foams, refrigeration and air-conditioning, propellants used in metered dose inhalers, and other applications. Emissions of HFCs, PFCs, and SF_6 from all other industrial sources are expected to be reduced significantly below 1990 levels, despite high growth rates of manufacturing in some sectors.

Nitrous Oxide

Nitrous oxide emissions are expected to rise from 433 Tg CO_2 Eq. in 2000 to 504 Tg CO_2 Eq. in 2020—an increase of 16.3 percent over the 20-year projection period. Although the largest single source of these emissions is agricultural soils, emissions from this source are projected to grow at only 9.8 percent. The fastest-growing sources of nitrous oxide emissions are the transportation sector and adipic and nitric acid production. Emissions from each of these sources are projected to grow by about 33 percent over the 20-year period (U.S. EPA 2001b).

Carbon Sequestration

Improved management practices on forest and agricultural lands and the regeneration of previously cleared forests resulted in annual net uptake (i.e., sequestration) of carbon during the 1990s (Table 5-8). Land-use decisions influence net carbon uptake long after their application.

A trend toward managed growth on private land since the early 1950s has resulted in a near doubling of the biomass density in eastern U.S. forests. More recently, the 1970s and 1980s saw a resurgence of federally sponsored forest management and soil conservation programs, which have focused on planting trees, improving timber management activities, combating soil erosion, and converting marginal croplands to forests. These efforts were maintained throughout the 1990s, and are expected to continue through the projection period. In addition, because most of the timber that is harvested from U.S. forests is used in wood products, and much of the discarded wood products are disposed of in landfills rather than by incineration, significant quantities of this harvested carbon are being transferred to long-term storage pools, rather than being released to the atmosphere.

Adjustments to Greenhouse Gas Emissions

Adjustments to the emissions reported in this chapter include adding the emissions—predominantly fuel-related—occurring in U.S. territories, and subtracting the international use of bunker fuels, both military and civilian (Table 5-9). Emissions from fuel use in U.S. territories are projected to grow from 51 Tg CO_2 Eq. in 2000 to 92 Tg CO_2 Eq. in 2020.[2] Bunker fuels in excludable uses are estimated to produce emissions of 110 Tg CO_2 Eq. in 2000 and 143 Tg CO_2 Eq. in 2020.[3]

Future of the President's February 2002 Climate Change Initiative

On February 14, 2002, the President committed the United States to reduce its greenhouse gas intensity by 18 percent over the next decade and announced a series of voluntary programs to achieve that goal. This includes proposed enhancements to the existing emissions registry under section 1605(b) of the 1992 Energy Policy Act that would both protect entities that register reductions from penalty under a future climate policy, and create transferable credits for companies that show real emission reductions. It also included expanding sectoral challenges and renewed support for renewable energy and energy efficiency tax credits contained in the *National Energy Policy*. The President indicated that progress would be evaluated in 2012 and that additional policies, including a broad,

TABLE 5-8 Projections of Carbon Sequestration (Tg CO_2)

Improved management practices on forest and agricultural lands and the regeneration of previously cleared forests resulted in annual net uptake (i.e., sequestration) of carbon during the 1990s. These practices are expected to continue throughout the projection period.

	2000	2005	2010	2015	2020
Carbon Sequestration (-)	1,205	1,175	1,144	1,049	1,053

Note: The above land-use sequestration estimates and projections are based on the U.S. government's August 1, 2000, submission to the UNFCCC on methodological issues related to the treatment of carbon sinks (U.S. DOS 2000). The projections are not directly comparable to the estimates provided in Chapter 3 of this report for two reasons: (1) the values provided in Chapter 3 use updated inventory information, and these projections have not been revised to reflect this new information; and (2) these projections are for a slightly different set of forest areas and activities than are accounted for in the national greenhouse gas inventory. A new set of projections that will be consistent with updated inventory estimates will be available from the USDA's Forest Service in early 2002. The trends provided in these projections serve to illustrate the impact of forces that are likely to influence carbon sequestration rates over the next decades.

TABLE 5-9 Adjustments to U.S. Greenhouse Gas Emissions (Tg CO_2 Eq.)

Adjustments to the emissions reported in this chapter include adding the emissions—predominantly fuel-related—occurring in U.S. territories, and subtracting the international use of bunker fuels, both military and civilian.

Type of Adjustment	2000	2005	2010	2015	2020
Emissions in U.S. Territories	+ 51	+ 59	+ 69	+ 79	+ 92
International Bunker Fuels	-110	-117	-128	- 136	-143
Net Adjustments	**- 59**	**- 58**	**- 59**	**- 57**	**- 51**

[2] The projected annual growth rate is 3 percent (U.S. DOE).
[3] The projected annual growth rate is 1.3 percent (U.S. DOE).

market-based program, would be considered in light of the adequacy of these voluntary programs and developments in our understanding of the science surrounding climate change. The consequences of this announcement have not yet been incorporated in current emission forecasts.

KEY UNCERTAINTIES AFFECTING PROJECTIONS

Any projection of future emissions is subject to considerable uncertainty. In the short term (less than 5 years), the key factors that can increase or decrease estimated net emissions include unexpected changes in retail energy prices, shifts in the price relationship between natural gas and coal used for electricity generation, changes in the economic growth path, abnormal winter or summer temperatures, and imperfect forecasting methods. Additional factors may influence emission rates over the longer term, such as technology developments, shifts in the composition of economic activity, and changes in government policies.

Technology Development (+ or -)

Forecasts of net U.S. emissions of greenhouse gases take into consideration likely improvements in technology over time. For example, technology-based energy efficiency gains, which have contributed to reductions in U.S. energy intensity for more than 30 years, are expected to continue. However, while long-term trends in technology are often predictable, the specific areas in which significant technology improvements will occur and the specific new technologies that will become dominant in commercial markets are impossible to forecast accurately, especially over the long term.

Unexpected scientific breakthroughs can cause technology changes and shifts in economic activity that have sometimes had dramatic effects on patterns of energy production and use. Such breakthroughs could enable the United States to dramatically reduce future greenhouse gas emissions. While government and private support of research and development efforts can accelerate the rate of technology change, the effect of such support on specific technology developments is difficult to predict.

The Administration has established a National Climate Change Technology Initiative (NCCTI) to strengthen basic research and develop advanced mitigation technologies for reducing greenhouse gas emissions. Success under the NCCTI could dramatically expand low-cost emission-reduction opportunities for the United States and the rest of the world.

In a modest high-technology case examined as part of the projections, energy use in 2020 under the high-technology regime is 5.6 percent lower than

Sample National Energy Policy Initiatives

The May 2001 *National Energy Policy* (NEP) is a long-term, comprehensive strategy to increase energy supplies; advance the development of new, environmentally friendly, energy-conservation technologies; and encourage cleaner, more efficient energy use (NEPD Group 2001). The NEP identified the major energy challenges facing the United States and developed 105 recommendations for addressing these challenges. When fully implemented, many of these recommendations will reduce domestic and international greenhouse gas emissions. Following is a snapshot of the NEP's proposed initiatives.

Reduce U.S. Energy Consumption

- Expand the ENERGY STAR® program to additional buildings, equipment, and services.
- Improve energy efficiency for appliances, and expand the scope of the appliance standards program.
- Encourage the use of combined heat-and-power operations and other clean-energy forms.
- Mitigate transportation congestion by both roadway improvements and information technology.
- Promote the purchase of fuel-efficient vehicles, including fuel-cell power plants for personal and heavy vehicles.
- Increase energy conservation in government facilities.

Increase U.S. Energy Supplies

- Enhance the reliability of U.S. energy supplies, and reduce U.S. reliance on energy imports.
- Increase domestic production of oil, natural gas, and coal.
- Expand support for advanced clean-coal technology research.
- Support the expansion of safe nuclear power technologies.
- Increase funding for research and development of renewable and alternative energy resources.
- Optimize the use of hydroelectric generation.
- Undertake long-term education and research into hydrogen fuels, advanced fuel cells, and fusion power.
- Extend tax credits for the production of electricity from biomass and wind resources.
- Create federal tax incentives to encourage landfill methane recovery.

Strengthen Global Alliances

- Expand international cooperation for energy research and development.
- Promote continued research on the science of global climate change.
- Cooperate with allies to develop cutting-edge technologies, market-based incentives, and other innovative approaches to address climate change.

in the reference case. By 2020, carbon emissions from energy use are 507 Tg CO_2 lower than in the reference case.

Regulatory or Statutory Changes (+ or -)

The current forecast of U.S. greenhouse gas emissions does not include the effects of any legislative or regulatory action that was not finalized before July 1, 2001. Consequently, the forecast does not include any increase in the stringency of equipment efficiency standards, even though existing law requires DOE to periodically strengthen its existing standards and issue new standards for other products. Similarly, the forecast does not assume any future increase in new building or auto fuel economy standards, even though such increases are required by law or are under consideration. Electric utility regulation is another area where further federal and state regulatory policy changes are anticipated, but are not reflected in the emissions forecast. Finally, the U.S. Congress is considering a broad range of legislative proposals, including many contained in the *National Energy Policy*, that will affect U.S. greenhouse gas emissions. Until specific legislative mandates are enacted, the forecast of emissions will not reflect their likely effects.

Energy Prices (+ or -)

The relationship between energy prices and emissions is complex. Lower energy prices generally reduce the incentive for energy conservation and tend to encourage increased energy use and related emissions. However, reduction in the price of natural gas relative to other fuels also encourages fuel switching that can reduce carbon emissions.

The AEO 2002 projections do not assume any dramatic changes in the energy price trends or the inter-fuel prices ratio that existed during most of the 1990s (U.S. DOE/EIA 2001a). Nor do they assume that the dramatic increases in energy prices that occurred from mid-2000 through the beginning of 2001 will persist. This view is supported by the precipitous decline in oil prices that occurred during the second half of 2001.

While some analysts project that further decreases in delivered energy prices will result from increased competition in the electric utility sector and improved technology, others project that large energy price increases may result from the faster-than-expected depletion of oil and gas resources, or from political or other disruptions in oil-producing countries.

Economic Growth (+ or -)

Faster economic growth increases the future demand for energy services, such as vehicle miles traveled, amount of lighted and ventilated space, and process heat used in industrial production. However, faster growth also stimulates capital investment and reduces the average age of the capital stock, increasing its average energy efficiency. The energy-service demand and energy-efficiency effects of higher growth work in offsetting directions. The effect on service demand is the stronger of the two, so that levels of primary energy use are positively correlated with the size of the economy.

In addition to the reference case used in developing the updated baseline, the AEO 2002 provides high and low economic growth cases, which vary the annual GDP growth rate from the reference case. The high-growth case raises the GDP growth rate by 0.4 percent. The low-growth case reduces the GDP growth rate by 0.6 percent.

- In the high-growth case 2020 energy use is 5.6 percent higher than in the reference case. By 2020, the high-growth economy is 8.8 percent larger than the reference economy, and carbon emissions from energy use are 462 Tg CO_2 Eq. greater than in the reference case.
- In the low-growth case 2020 energy use is 5.4 percent lower than in the reference case. By 2020, the low-growth economy is 9.7 percent smaller than the reference economy, and carbon emissions from energy use are 395 Tg CO_2 Eq. lower than in the reference case.

Faster-than-expected growth during the late 1990s was the major cause of higher-than-expected U.S. greenhouse gas emissions during this period. The U.S. economic slowdown in 2001 and post-September 11 fallout may well result in lower-than-expected greenhouse gas emissions during 2002 and the immediately following years. However, the long-run economic growth path remains unchanged.

Weather (+ or -)

Energy use for heating and cooling is directly responsive to weather variation. The forecast of emissions assumes 30-year average values for population-weighted heating and cooling degree-days. Unlike other sources of uncertainty, for which deviations between assumed and actual trends may follow a persistent course over time, the effect of weather on energy use and emissions in any particular year is largely independent year to year. For the United States, a swing in either direction of the magnitude experienced in individual years during the 1990s could raise or lower annual emissions by 70 Tg CO_2 Eq. relative to a year with average weather that generates typical heating and cooling demands. While small relative to total emissions, a change of this magnitude is significant relative to the year-to-year growth of total emissions.